# Assessing the Dietary Exposure of Harbour Seals (*Phoca vitulina*) to Persistent Organic Pollutants (POPs) in the Strait of Georgia (British Columbia, Canada) and Puget Sound (Washington State, USA)

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## Abstract
Elevated Persistent Organic Pollutants (POPs) concentrations have been detected in high trophic level wildlife and have been associated with endocrine disruption and other adverse health effects. Recent evidence indicates that harbour seals *(Phoca vitulina)* inhabiting Puget Sound, WA are approximately seven times more contaminated with polychlorinated biphenyls (PCBs) than those inhabiting the Strait of Georgia, BC. We are currently using an ecosystem approach to characterize the accumulation of complex mixtures of POPs in harbour seal food chains using such tools as congener-specific contaminant analyses, stable isotope ratios, fatty acid signatures, and multivariate statistical methods. Weighted, prey-specific "food baskets," representing realistic average dietary intakes for harbour seals, were created following sampling of preferred prey species from the two basins. Total PCB concentrations in the Puget Sound seal food basket were found to be seven times higher than the Strait of Georgia seal food basket, consistent with previous observations of harbour seals in these transboundary waters. Stable carbon and nitrogen isotope ratios in seals, prey species, and food baskets suggest that Puget Sound harbour seals ($d^{13}C$ –15.8‰/$d^{15}N$ 14.4‰) feed slightly higher in the food chain than Strait of Georgia harbour seals ($d^{13}C$ –19.2‰/$d^{15}N$ 12.9‰). Based on these results, we estimate that the estimated daily dietary intake (EDI) of PCBs by a 25 kg harbour seal is 0.03mg/kg·bw/day for Strait of Georgia seals and 0.21mg/kg·bw/day for Puget Sound seals. Our research suggests that harbour seals are vulnerable to accumulating relatively high concentrations of POPs through the ingestion of contaminated prey items, and highlight the need for further research into the sources of such persistent contaminants in this transboundary region.

## Extended Abstract
Persistent Organic Pollutants (POPs) are lipophilic or "fat soluble" compounds that can bioaccumulate within organisms and biomagnify to high trophic levels with marine and terrestrial food webs. POPs include industrial compounds and flame retardants such as polychlorinated biphenyls (PCBs), polychlorinated naphthalenes (PCNs), polybrominated diphenyl ethers (PBDEs), polybrominated biphenyls (PBBs), industrial by-products such as polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and organochlorine pesticides (eg. DDT, HCH). Elevated exposure to POPs has been linked to immunotoxicity, endocrine disruption, reproductive impairment, and developmental abnormalities in humans and wildlife (Ross2000; Ross and Birnbaum2003).

Harbour seals (*Phoca vitulina*) inhabiting Puget Sound, Washington, USA, are approximately seven times more contaminated with PCBs than those inhabiting the Strait of Georgia, British Columbia, Canada (Ross et al. 2003). Two mechanisms may explain these differences: (1) regional variation in contaminant inputs, or (2) differences in seal prey selection. Puget Sound harbour seals consume a wide variety of prey species, whereas seals in the Strait of Georgia rely largely on two species: Pacific hake (*Merluccius productus*) and Pacific herring (*Clupea harengus pallasi*) (Olesiuk et al. 1990; Olesiuk1993).

"Food basket" or "market basket" studies have traditionally been used in human health risk assessments to assess "realistic" exposure to contaminants from all sources through dietary intake (Bolles et al. 1999; Newsome et al. 2000). Given the existing information on the dietary preferences of harbour seals inhabiting the two basins, such an approach offers a basis for a realistic assessment of contaminant exposure in free-ranging seals. We carried out a food basket approach to estimate realistic dietary exposures to "real world" mixtures of POPs in harbour seals. We collected samples

of preferred prey species from both Puget Sound and Strait of Georgia as itemized by earlier studies. Weighted, prey-specific food baskets, were then constructed for subsequent analysis for PCBs, PCDDs, PCDFs, PBDEs, PBBs, PCNs, and organochlorine pesticides (including DDT, HCB, HCH, Heptachlor, Aldrin, Chlordane, Non-Achlor, and Mirex).

Puget Sound food basket had higher total concentrations of all chemicals detected than the Strait of Georgia food basket with the exception of hexachlorobenzene (HCB). ΣPCBs, ΣPBDEs, and ΣDDTs were found at the highest concentrations in both food baskets. Total PCB concentrations in the Puget Sound seal food basket were found to be three times higher on a wet weight basis and seven times higher on a lipid weight basis than the Strait of Georgia seal food basket, consistent with previous observations of elevated PCB concentrations in Puget Sound seals. Stable carbon and nitrogen isotope ratios in seal blubber, prey species, and food baskets suggest that although Puget Sound harbour seals ($\delta^{13}C$ –15.8‰/$\delta^{15}N$ 14.4‰) may feed slightly higher in the food chain than Strait of Georgia harbour seals ($\delta^{13}C$ –19.2‰/$\delta^{15}N$ 12.9‰), a trophic level-associated bioaccumulation of contaminants does not explain inter-basin differences in the contamination of seals.

In order to assess whether prey selection by the seals of the two basins explained contaminant differences between Puget Sound and Strait of Georgia food baskets, we constructed two additional food baskets. The first relied on Strait of Georgia prey preferences but was composed of Puget Sound samples; the second relied on Puget Sound prey preferences but was composed of Strait of Georgia samples. If the same prey species are equally contaminated in both basins, we would predict that if Puget Sound prey samples were used to construct a Strait of Georgia food basket (i.e. the "menu" consumed by Strait of Georgia seals), this would result in decreased contaminant concentrations compared to the original Puget Sound food basket. On the other hand, if the same prey species were more contaminated in Puget Sound as a consequence of local environmental contamination, we would expect no change, or perhaps an increase, when Puget Sound prey samples were used to construct a Strait of Georgia food basket. We found Puget Sound food basket PCB levels to increase with the Strait of Georgia seal diet and Strait of Georgia food basket PCB levels to decrease with the Puget Sound seal diet. This suggests that *regional contamination* rather than *prey selection* more likely explains the degree of contamination of the original Puget Sound food basket and as a consequence, harbour seals.

Based on our results, we estimate the daily dietary intake (EDI) of PCBs, on a wet weight basis, by a 25 kg harbour seal to be 1.2 ug/kg·bw/day for Strait of Georgia seals and 3.9 ug/kg·bw/day for Puget Sound seals; and for an 85 kg harbour seal to be 0.5 ug/kg·bw/day for Strait of Georgia seals and 1.7 ug/kg·bw/day for Puget Sound seals. This suggests that young harbour seals are exposed to higher concentrations of POPs than adults, and may therefore be at increased risk to adverse health effects.

This study represents the first time that a food basket approach has been applied to estimating POP intakes in a marine mammal. Results will be more comprehensively evaluated elsewhere (Cullon et al. 2003). We conclude that a food basket approach represents: (1) a relatively straight forward method of assessing dietary exposure to "real world" mixtures of POPs; (2) an integrated dietary signal as a basis for understanding dietary exposure, biomagnification, metabolism, and health risks associated with exposure; and (3) additional support for the use of the harbour seal as a sentinel of marine ecosystem contamination.

## References

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